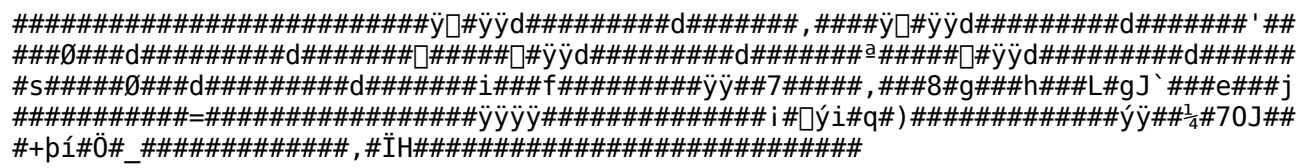

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TAXONOMY OF UNSAFE OPERATIONS: A HUMAN FACTORS APPROACH TO ACCIDENT INVESTIGATION

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þãÿÿÿ####ÿÿ#####ÿ□#ÿÿd#########K#########^###Scott A. Shappell, Ph.D.
COMNAVAIRLANTDouglas A. Wiegmann, Ph.D.University of North Florida

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d#2#######C### It is not surprising then, that human error has been implicated in 60-80% of occupational accidents. In fact, while occupational accidents solely attributable to environmental and mechanical factors have been greatly reduced over the last several years, those attributable to human error continue to plague organizations.t

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èýÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########£###□Human beings by their very nature make errors; therefore, it is unreasonable to expect that human performance can proceed error free.□ Shappell & Wiegmann, 1996#

###ÿÿ#####ÿ#ÿÿd#########d#############Human error has been implicated in 60-80% of most occupational accidents.Although the overall rate of many types of accidents has declined steadily during the past 20 years, reductions in human error-related accidents have not paralleled those related to mechanical/environmental factors.For example, U.S. Naval aviation accidents attributable to human and mechanical/environmental factors were nearly equal in 1977. Yet by 1992, accidents solely attributable to mechanical/environmental factors had been virtually eliminated while those attributable to human error had been reduced by only 50% (Shappell & Wiegmann, 1996).If aviation accidents are to be reduced further, more needs to be done to prevent the occurrence of human error and/or to design more error-tolerant systems.#

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Engineering and mechanical failures are observable and quantifiable, whereas human error and its causes are generally intangible and elusive. Most accident investigators are previous operators or designers with traditional engineering rather than human factors backgrounds. Traditionally the emphasis of most accident databases has been on the identification of injuries and losses as they relate to mechanical causes. Even when human factors are identified, the reporting systems typically used are not designed around any particular framework of human error.

###ÿÿ#####ÿØ#ÿÿd#########d#########3###Engineering and mechanical failures are observable and quantifiable, whereas human error and its causes are generally intangible and elusive. As such technological improvements are more readily identifiable then improvements based on human factors principles. Most accident investigators are previous operators or designers with traditional engineering rather than human factors backgrounds. Most mishap databases were designed by engineers and operators, NOT psychologists and human factors experts. As such, they are generally not conducive to traditional human error analysis.Even when human causal factors are identified, the reporting system typically used are not designed around any theoretical framework of human error. This situation makes the identification and development of countermeasures onerous..

###ÿÿ#####ÿØ#ÿÿd#########d#########°###Even if these additional causal factors had been classified, however, restricting the analysis to unsafe acts and the condition of operators would still tell only part of the story. Latent errors committed by officials within the management hierarchy, such as line managers and supervisors, also may effect the tragic sequence of events characteristic of an accident (Reason, 1990).Viewed from this perspective, the unsafe acts of the operator are the end result of a long chain of causes whose roots originate in the upper echelons of the system (Reason, 1994).Any comprehensive analysis of accidents should therefore provide for the classification of organizational factors as well.

###ÿÿ#####ÿ#ÿÿd#########d#########X###The Domino Theory of Accident Causation (Bird, 1974) describes five dominos in the accident sequence, each effecting the toppling of the next. Domino One - safety and/or loss control as a function of management. Loss control here refers to the management of operational losses. Domino Two - basic causes such as personal and job related factors begin to appear. Examples include knowledge, skill, motivation, and other human factors associated with the individual, as well as job related factors such as work standards, normal wear and tear, and abnormal usage of equipment. Domino Three - immediate causes are those substandard practices and substandard conditions that lead to the actual accident. Domino Four - impact with an energy source (the accident) Domino Five - personal injury and/or damage to propertyUnderlying this theory of accident causation is the premise that the removal of any of the preceding four dominos would eliminate injury and/or damage.Most safety programs target immediate rather than basic causes. Unfortunately however, like medicine, simply treating symptoms (immediate causes) while ignoring the underlying disease state (basic cause) only masks the real problems. Ultimately then, if a permanent change is to be realized, modifications must be made within management aimed at effecting basic causes and subsequent dominos.

###ÿÿ#####ÿ□#ÿÿd#########d#########¤###The Taxonomy of Unsafe Operations draws upon aspects of Edward's SHEL model, Bird's domino theory, and Reason's classification of unsafe acts, to account for human accident causal factors, including the condition of operators as well as organizational and/or supervisory error.Edward's multi-dimensional SHEL model serves as a foundation for the taxonomy. Central to this scheme is the human (liveware). The liveware portion of the SHEL model was chosen with the understanding that the human does not operate in a vacuum. Clearly, the remaining components are important, yet the human has proven central to most accidents and hence where our taxonomy begins.The liveware component was expanded using Bird's domino theory as a backbone. As with other taxonomies examined, the domino theory in its original form proved incomplete. While the underlying structure of the framework was preserved, individual dominoes have been modified to describe Unsafe organizational and/or supervisory practices Unsafe conditions of the operators Unsafe acts of operators Dominoes four (accident) and five (personal injury or property damage) remain unchanged and were combined for simplicity.

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ûi#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########B### Intrusions Omissions Reversals
Misordering of items Mistiming
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###ÿÿ#####ÿ□#ÿÿd#########d#########»###Unintended Unsafe Acts These are actions which unwittingly deviate from planned intentions due to failures of execution and/or memory and manifest as either slips or lapses.Slips - are characteristic of attention failures and take the form of inadvertent activations, interference errors, omissions following interruptions, mistimed attentional checks, and order reversals, among others.Lapses - arise from memory failures and may appear as omitted items in a checklist, place losing, or forgotten intentions.Both slips and lapses are believed to occur at a largely automatic, skill based, level of processing. As such, both are particularly sensitive to monitoring failures by the individual.)

###ÿÿ#####ÿ□#ÿÿd#########d#########»###Unintended Unsafe Acts These are actions which unwittingly deviate from planned intentions due to failures of execution and/or memory and manifest as either slips or lapses.Slips - are characteristic of attention failures and take the form of inadvertent activations, interference errors, omissions following interruptions, mistimed attentional checks, and order reversals, among others.Lapses - arise from memory failures and may appear as omitted items in a checklist, place losing, or forgotten intentions.Both slips and lapses are believed to occur at a largely automatic, skill based, level of processing. As such, both are particularly sensitive to monitoring failures by the individual.#

##ÿ□#ÿÿd#########d#########9#Ê###*#e#§
      □#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########¥### Rule-based   -
Misapplication of a good rule   - Application of a bad rule Knowledge-based
- Inaccurate or incomplete   knowledge of the problem#

###ÿÿ#####ÿØ#ÿÿd#########d#############Intended Unsafe ActsMistakes - represent intentional behavior that proceeds as intended, yet the plan proves inadequate to achieve the desired outcome. Since much of behavior tends to be based upon previous experience or rules, mistakes are further classified as either rule-based or knowledge-based (Rasmussen, 1986). Rule-based mistakes take the form of: Misapplication of a good rule - the use of preprogrammed behaviors that were appropriate in the context they were learned, but prove inadequate. Application of a bad rule - learned inappropriate, inadvisable, or inelegant programs that may succeed by chance in the context they were learned, yet prove inadequate. Knowledge based mistakes occur when sufficient experience is not available to solve the problem; therefore, individuals must resort to computationally powerful, yet slow and effortful, problem solving behavior. Individuals are left open to a wide range of error types, including cognitive workspace limitations, confirmation bias, and overconfidence in problem solving.#

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!#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########¸### Routine Violations      - Habitual
departures from rulescondoned by management Exceptional Violations      -
Isolated departures from rules           NOT condoned by management
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###ÿÿ#####ÿØ#ÿÿd#########d#############Intended Unsafe ActsViolations represent the intentional departure from practices deemed necessary for safe operations. Routine violations tend to be habitual by nature constituting a part of the individual's behavioral repertoire (i.e., driving consistently 5-10 mph faster than allowed by law). Often routine violations are perpetuated by a system that tolerates such departures. Exceptional violations, on the other hand, are isolated departures from authority not necessarily indicative of an individuals typical behavior pattern nor condoned by management (an isolated instance of driving 105 mph in a 55 mph zone is considered an exceptional violation, not because of its extreme nature, but because its neither typical of the individual nor condoned by authority.)#

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#######d#########9#È###Ìöc#Zû#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########d### Spatial Disorientation Hypoxia Visual Illusions Motion Sickness Medical Illness Intoxication

###ÿÿ#####ÿ□#ÿÿd#########d#########«###Substandard ConditionsAs in the original Domino Sequence of Accident Causation, when failures occur in supervision and/or management, basic causes will emerge. However, unlike the original theory, the present description is restricted to those factors directly associated with the condition of the operator in the accident sequence. Adverse Physiological States - refers to those medical or physiological conditions that preclude safe operations. Particularly important to some operational settings are conditions such as spatial disorientation, hypoxia, visual illusions, physical fatigue, and the myriad of pharmacological and medical abnormalities known to affect performance.#

ö÷##ü##ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########z### Loss of Situational Awareness Circadian dysrhythmia Alertness (Drowsiness) Overconfidence Complacency Task Fixation

###ÿÿ#####ÿ□#ÿÿd#########d#############Substandard ConditionsAs in the original Domino Sequence of Accident Causation, when failures occur in supervision and/or management, basic causes will emerge. However, unlike the original theory, the present description is restricted to those factors directly associated with the condition of the operator in the accident sequence. Adverse Mental States - refers to those psychological and/or mental conditions that impact negatively on performance. Principle among adverse mental states are the loss of situational awareness, cognitive effects of sleep loss and circadian dysrhythmia, and other psychological diagnoses that effect safety. Also included in this category are personality traits and pernicious attitudes such as overconfidence, complacency, and misplaced motivation.#

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###¦õ¥#fü½#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########v### Lack of Sensory Input
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Limited Reaction Time Insufficient Physical Capabilities Insufficient Intelligence/Aptitude

###ÿÿ#####ÿ□#ÿÿd#########d#########|###Substandard ConditionsAs in the original Domino Sequence of Accident Causation, when failures occur in supervision and/or management, basic causes will emerge. However, unlike the original theory, the present description is restricted to those factors directly associated with the condition of the operator in the accident sequence. Physical/Mental Limitations - refers to those instances when necessary visual or aural information is not available due to limitations inherent within the sensory system. For instance, in aviation, this most often includes not seeing other aircraft, power lines and other obstacles due to the size or contrast of the object in the visual field. Also included are those instances when time to process information or respond exceeds human capacity (i.e., the individual simply could not physically respond or decide quickly enough to avert the accident).

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+#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########O### Poor Dietary Practices Overexertion
While Off Duty Excessive □Voluntary□ PT  þ
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###ÿÿ#####ÿ□#ÿÿd#########d#########ß###Substandard Practices

Mistakes/Misjudgements - typically include behaviors that do not violate existing instructions or standard operating procedures, but may reduce the operating capabilities of the individual. For example, running 10 miles before piloting an aircraft may impair the physical and mental capabilities of the individual enough to degrade performance and elicit unsafe acts. However, there may be no rules governing such behavior, other than reasonable judgment.ÿ

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Õ#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########x### Not Working as a Team Poor Aircrew Coordination Improper Briefing Before a Mission Inadequate Coordination of Flight

###ÿÿ#####ÿ#ÿÿd#########d#########¬###Substandard PracticesCrew Resource Mismanagement - was created to account for occurrences of poor crew coordination in selected occupational settings. Also included are those instances when individuals directly responsible for the conduct of the operations fail to coordinate and/or supervise operations appropriately. For instance, within aviation this category is reserved for aircrew who function during the flight as aircraft commanders, flight leaders, section leaders, etc. Elements of this category differ from those classified as unsafe supervision, since those generally involve individuals in positions of higher authority detached from the direct conduct of operations.

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§#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########Y### Violation of Crew Rest Requirements
Violation of Bottle-to-Brief Rules Self-Medicating#
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###ÿÿ#####ÿ□#ÿÿd#########d#########Q###Substandard PracticesReadiness Violations - refers to the disregard for rules, regulations, and instructions that govern the individual readiness to perform. These include such behaviors as violating crew rest requirements and alcohol restrictions. Both may lead to altered behavioral states and lead to the occurrence of unsafe acts.#

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############################################ÿ#ÿÿd#########d#########9####gõ##
      ýM#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d############# Loss of Supervisory
Situational      Awareness Unseen Unsafe Conditions/Hazards     - Unrecognized
Adverse Aeromedical         Conditions     - Life Changes such as Divorce, Death
in the Family, Legal/Financial/          Personal Problems
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###ÿÿ#####ÿØ#ÿÿd#########d#########q###Unforseen Unsafe SupervisionIn a broad sense, unintended unsafe supervision can be viewed as those unsafe management and/or supervisory practices that go unforeseen, yet are not the result of negligence or adverse behavior. This category is typically viewed from the perspective of the middle-manager, not the CEO or higher organizational level. Unrecognized Hazardous Operations - can be viewed as a loss of supervisory situational awareness. Though somewhat broad, it includes those instances when unsafe conditions or hazards exist yet go unseen or unrecognized by the untrained or over-tasked supervisor. Selected examples include: Medical conditions such as illness or fatigue that adversely effect performance The insidious effects of recent life changes such as divorce, death of a family member, legal difficulties, financial discord, and other personal difficulties#

##ÿ□#ÿÿd#########d#########9#*###ÖõÅ#U
üW#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########L### Lack of Technical Specifications
Lack of Instructions Lack of Procedures

###ÿÿ#####ÿØ#ÿÿd#########d#########(###Unforseen Unsafe SupervisionIn a broad sense, unintended unsafe supervision can be viewed as those unsafe management and/or supervisory practices that go unforeseen, yet are not the result of negligence or adverse behavior. This category is typically viewed from the perspective of the middle-manager, not the CEO or higher organizational level. Inadequate Documentation - typical of most systems, particularly new ones where the "bugs" have yet to be worked out. Accounting for all possible contingencies through technical specifications, instructions, regulations, and standard operating procedures is an extremely difficult task, at best. As a result, accidents, incidents, and hazards continue to be a common way of identifying deficiencies in existing documentation, often after tragedy has struck.

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#ÿÿd#########d#########>### Poor equipment design that contributes      to the
accident
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###ÿÿ#####ÿ□#ÿÿd#########d#########-###Unforseen Unsafe SupervisionIn a broad sense, unintended unsafe supervision can be viewed as those unsafe management and/or supervisory practices that go unforeseen, yet are not the result of negligence or adverse behavior. This category is typically viewed from the perspective of the middle-manager, not the CEO or higher organizational level. Inadequate Design - often times design deficiencies as specified by those higher in the management hierarchy go either unforeseen or unchanged for reasons beyond the control of line management and supervisors.#

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±#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########F### Failure to Administer Proper
Training Lack of Professional Guidance
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###ÿÿ#####ÿ□#ÿÿd#########d#########Y###Known Unsafe SupervisionThis subdivision refers to the unsafe management of operations which were a direct result of supervisory action or inaction.Inadequate Supervision - refers to management of the individual on a personal level. It is expected that individuals will receive adequate training, professional guidance, and operational leadership, and that all will be managed appropriately. Unfortunately, supervision may prove inappropriate, improper, or may not occur at all. Regardless, inadequate supervision is viewed as a function of some action, or purposeful inaction by the supervisor.#

###ÿÿ#####ÿ□#ÿÿd#########d#########O###Known Unsafe SupervisionThis subdivision refers to the unsafe management of operations which were a direct result of supervisory action or inaction.Planned Inappropriate Operations - refers to the management of the individual as an asset among many others (i.e., a "cog in the wheel"). Occasionally, the operational tempo and/or schedule is planned such that individuals are put at unacceptable risk, crew rest is jeopardized, and ultimately performance is adversely affected. Such operations, though arguably unavoidable emergency situations, are unacceptable during normal operations.#

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F#ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########T### Failure to Correct Inappropriate
Behavior Failure to Correct a Safety Hazard
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###ÿÿ#####ÿ□#ÿÿd#########d#########j###Known Unsafe SupervisionThis subdivision refers to the unsafe management of operations which were a direct result of supervisory action or inaction.Failed to Correct Problem - refers to those instances when deficiencies among individuals, equipment, training or other related safety areas are □known□ to the supervisor yet are allowed to continue uncorrected.

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##ÿÿ####ÿÿ#####ÿØ#ÿÿd#########d#########^### Not Adhering to Rules and
Regulations Willful Disregard for Authority by       Supervisors
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###ÿÿ#####ÿ□#ÿÿd#########d#########B###Known Unsafe SupervisionThis subdivision refers to the unsafe management of operations which were a direct result of supervisory action or inaction.Supervisory Violations - refers to those instances when existing rules, regulations, instructions, or standard operating procedures are not adhered to by supervisors when managing assets. Moreover, that it is considered an "intended" act implies a willful disregard for authority. This is quite different from inadvertently or unwittingly violating the rules, considered unrecognized hazardous operations as described earlier.

###ÿÿ#####ÿ□#ÿÿd#########d#########G###THE TAXONOMY OF UNSAFE OPERATIONSReview the taxonomy in its entirety..

###ÿÿ#####ÿ#ÿÿd#########d#########û###Topic: Demonstration of Accident AnalysesLearning Mode: LectureSkill Acquired: An analysis of selected accidents from several transportation modes will be demonstrated using the Taxonomy of Unsafe OperationsDuration: Approximately 60 minutes

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###ÿÿ#####ÿ□#ÿÿd#########d#########G###THE TAXONOMY OF UNSAFE OPERATIONSReview
the taxonomy in its entirety..
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1996########'###Taxonomy of Unsafe Operations - Update###########Shappell &
Wiegmann########################4###h:\applicat\msoffice\template\clrovrhd\soar
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